Figure 10-1

- Inspection before/after production
  - Acceptance sampling
- Inspection and corrective action during production
  - Process control
- Quality built into the process
  - Continuous improvement

The least progressive → The most progressive

Figure 10-2

- Inputs → Transformation → Outputs
- Acceptance sampling → Process control → Acceptance sampling

Figure 10-3

- Cost vs. Amount of Inspection
  - Total cost
  - Cost of inspection
  - Cost of passing defectives

Where to Inspect in the Process

- Raw materials and purchased parts
- Finished products
- Before a costly operation
- Before an irreversible process
- Before a covering process
10-7 Quality Control

• **Statistical Process Control**: Statistical evaluation of the output of a process during production
  - 100% inspection is not feasible
    ⇒ Sample a portion of the process
• **Quality of Conformance**: A product or service conforms to specifications

10-8 Quality Control

• **Control Chart**
  - **Purpose**: to monitor process output to see if it is random
  - A time ordered plot representative sample statistics obtained from an on going process (e.g. sample means)
  - Upper and lower control limits define the range of acceptable variation

10-10 Quality Control

• The Control Process
  - Define
  - Measure
  - Compare
  - Evaluate
  - Correct
  - Monitor results

10-11 Quality Control

• Variations and Control
  - **Random variation**: Natural variations in the output of a process, created by countless minor factors
  - **Assignable variation**: A variation whose source can be identified

10-12 Quality Control

• **Statistical Process Control**
  - Variations and Control
  - The Control Process
  - Sampling Distribution

The dispersion (spread) of a series of means is less than the actual process dispersion. E.g. plotting the means of 20 samples of 5 each has less dispersion than plotting the 100 total samples individually (Central Limit Theorem in statistics).
Quality Control

**Figure 10-6 Normal Distribution**

\[ \sigma = \text{Standard deviation} \]

\[ -3\sigma \quad -2\sigma \quad \text{Mean} \quad +2\sigma \quad +3\sigma \]

- 68% of the data lies within \( \pm 1\sigma \)
- 95% of the data lies within \( \pm 2\sigma \)
- 99.7% of the data lies within \( \pm 3\sigma \)

**Figure 10-7 Control Limits**

- A process is "out of control" if it creates output beyond the specified limits.

**SPC Errors**

- **Type I error**
  - Concluding a process is *not* in control when it actually *is*.
  - Probability of a Type I error is \( \alpha \) and is the area outside of the LCL/UCL.
  - \( \alpha \) affected by shape of sampling distribution.

- **Type II error**
  - Concluding a process is in control when it is not.

**Figure 10-8 Type I Error**

\( \alpha = \text{Probability of a Type I error} \)

**Observations from Sample Distribution**

Observations of a process (e.g. drying time) vary around a mean, i.e. they are dispersed around an average.
Control Charts for Variables

Variables generate data that are measured.

- **Mean** control charts (uses average of data)
  - Used to monitor the central tendency of a process.
  - X bar charts

- **Range** control charts (uses range of data)
  - Used to monitor the process dispersion
  - R charts

Mean and Range Charts

Figure 10.10A

Sampling Distribution

- **x-Chart**
  - Detects shift

- **R-chart**
  - Does not detect shift (the range is acceptable)

Figure 10.10B

Sampling Distribution

- **x-Chart**
  - Does not reveal increase

- **R-chart**
  - Reveals increase in dispersion

Problems from textbook

- Data
- Creating information from data (using equations)
- Means
- Grand means
- Lower/Upper control limits

Control Chart for Attributes

- **p-Chart** - Control chart used to monitor the proportion of defectives in a process
  - Pass/fail, good/bad

- **c-Chart** - Control chart used to monitor the number of defects per unit
  - Cannot count “non-occurrences”
  - Count # of errors that occurred, but cannot count # of errors that did not occur

Attributes generate data that are counted.

Use of p-Charts

Table 10.3

- When observations can be placed into two categories.
  - Good or bad
  - Pass or fail
  - Operate or don’t operate
- When the data consists of multiple samples of several observations each
Use of c-Charts

- Use only when the number of occurrences per unit of measure can be counted; non-occurrences cannot be counted.
  - Scratches, chips, dents, or errors per item
  - Cracks or faults per unit of distance
  - Breaks or Tears per unit of area
  - Bacteria or pollutants per unit of volume
  - Calls, complaints, failures per unit of time

Table 10.3

Use of Control Charts

- At what point in the process to use control charts
- What size samples to take
- What type of control chart to use
  - Variables
  - Attributes

Problems from textbook

Run Tests

- Run test – a test for randomness
- Any sort of pattern in the data would suggest a non-random process
- All points are within the control limits - the process may not be random

Nonrandom Patterns in Control charts

- Trend
- Cycles
- Bias
- Mean shift
- Too much dispersion

Figure 10-12

Counting Above/Below Median Runs

(7 runs)
10-31 Quality Control

Figure 10-13

Counting Up/Down Runs

Figure 10-14

Too few runs
Acceptable number of runs
Too many runs

Figure 10-15

A. Process variability matches specifications
B. Process variability well within specifications
C. Process variability exceeds specifications

Problems from textbook

10-32 Quality Control

• Tolerances or specifications
  • Range of acceptable values established by engineering design or customer requirements
• Process variability
  • Natural variability in a process
• Process capability
  • Process variability relative to specification

10-33 Quality Control

Process Capability

A. Process variability matches specifications
B. Process variability well within specifications
C. Process variability exceeds specifications
Process Capability Ratio

Process capability ratio, \( Cp = \frac{\text{specification width}}{\text{process width}} \)

\[ Cp = \frac{\text{Upper specification} - \text{lower specification}}{6\sigma} \]

Figure 10-16

Problems from textbook

Improving Process Capability

- Simplify
- Standardize
- Mistake-proof
- Upgrade equipment
- Automate

Taguchi Loss Function

Limitations of Capability Indexes

1. Process may not be stable
2. Process output may not be normally distributed
3. Process not centered but \( C_p \) is used